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The 2017 Joint U.S. and Canada Pacific Hake Integrated Acoustic and Trawl Survey:
Cruise Report SH-17-07

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National Oceanic and Atmospheric Administration
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This survey was conducted under the authority of the following permits: Alaska Department of Fish and Game Fish Resource Permit CF-17-051, California Department of Fish and Wildlife Scientific Collecting Permit SC-13614, NMFS Biological Opinion WCR-2016-5783, NMFS Determination of Take Authorization under a Biological Opinion 16335-3R, NMFS West Coast Region Scientific Research Permit SRP-09-2017, NOAA Channel Islands National Marine Sanctuary Research Permit CINMS-2017-001, and Oregon Department of Fish and Wildlife 2017—Scientific Taking Permit—Fish #21051.

Introduction

Pacific hake (*Merluccius productus*), hereafter hake, is an important commercial marine fish found off the west coast of North America. Over the last ten years (2008–17), coastwide annual harvests have averaged 276,288 metric tons (Edwards et al. 2018), with U.S. and Canadian catches averaging 220,094 metric tons and 56,194 metric tons, respectively. In 2017, the coastwide catch was 440,944 metric tons. In addition to its commercial importance, hake is also a key trophic species and the most abundant groundfish in the California Current Large Marine Ecosystem (Sherman 1991). Because coastal hake have a prominent economic and ecological value, integrated acoustic and trawl (IAT) surveys have been used to assess the abundance, distribution, and biology of hake along the west coast of the U.S. and Canada (Fleischer et al. 2005). Beginning in 1977, the Alaska Fisheries Science Center (AFSC) conducted triennial IAT surveys in U.S. and Canadian waters, and in 1990 the Department of Fisheries and Oceans Canada (DFO) started conducting annual IAT surveys in Canadian waters. After the 2001 survey, responsibility for the U.S. portion of the IAT survey was transferred from AFSC to the Northwest Fisheries Science Center (NWFSC), and the survey frequency was increased from triennial to biennial. In addition, since 1995 the U.S. and Canada have collaborated in assessing hake: the triennial IAT surveys of 1995, 1998, and 2001 were conducted jointly by AFSC and DFO, and IAT surveys since 2003 have been conducted jointly by NWFSC and DFO.

The results presented here are from the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey. This report provides a brief description of the methods used in the survey and summarizes the distribution, biological composition, and biomass of hake in U.S. and Canadian waters off the Pacific coast. It also summarizes results of acoustic system calibrations, an intervessel calibration (IVC), and secondary survey objectives.

Materials and Methods

Scientists from the Fishery Resource Analysis and Monitoring (FRAM) Division at NWFSC and the Pacific region of DFO led the 2017 IAT survey aboard the NOAA Ship *Bell M. Shimada*—a 209-foot acoustically quieted Fisheries Survey Vessel—and the *Nordic Pearl*, a chartered 115-foot Canadian fishing vessel. Both vessels are stern trawlers equipped for fisheries research, while the *Shimada* is also equipped for oceanographic research.

The survey began near Point Conception, California, proceeded north along the west coast of the United States and Canada (surveying Queen Charlotte Sound, Hecate Strait, and the west side of Haida Gwaii), and finished in Dixon Entrance (Figure 1). Hake aggregations were targeted for trawling along the entire survey area. The *Shimada* surveyed between 25 June and 7 September (Table 1), and the *Nordic Pearl* surveyed between 17 August and 6 September. Acoustic transects assumed an east–west orientation, were spaced 10 nautical miles (nmi) apart, and ranged from the 50-m isobath (or as close to shore as was safely navigable) to either the 1,500-m isobath or a location 35 nmi west of the inshore waypoint, whichever was farther offshore. If hake were detected at the offshore end of a transect, the vessel proceeded west to the end of the hake sign and then beyond for an additional 0.5 nmi to ensure that the end of the aggregation was located. This protocol was in place to ensure that the interpolation algorithm used for calculating hake biomass performed correctly at the offshore ends of transects. Transects were traversed sequentially, usually in alternating directions. In 2017, transects along Haida Gwaii and into Southeast Alaska were surveyed from south to north, instead of the customary north to south of previous hake surveys. Along parts of Washington and Vancouver Island, the *Shimada* and the *Nordic Pearl* interleaved transects. Six transects in Dixon Entrance had a north–south orientation.

Acoustic Sampling

Equipment

Five Simrad split-beam transducers, operating at 18, 38, 70, 120, and 200 kHz, were mounted on the bottom of the *Shimada*'s retractable centerboard. During the survey, to reduce interference from bubbles, the centerboard was extended to its maximum depth, thereby positioning the transducers at a depth of 9.15 m below the water surface. Acoustic data from the 18-, 38-, and 120-kHz transducers were collected with a Simrad EK60 scientific echosounder system coupled with an ER60 software system (version 2.4.3). Acoustic data from the 70- and 200-kHz transducers were collected with a Simrad EK80 broadband scientific echosounder (version 1.1.83) during calibrations of the acoustic systems and during Leg 5 of the survey.

The *Shimada* was equipped with a Teledyne RD Instruments Ocean Surveyor 75-kHz Acoustic Doppler Current Profiler (ADCP) system and a Simrad ME70 scientific multibeam echosounder system, but the ME70 system was not used because of interference with the other acoustic systems. A Simrad K-Sync unit was used to synchronize pulse sequences from the EK60, EK80, and ADCP acoustic instruments.

Acoustic data on the *Nordic Pearl* were collected with a Simrad EK60 scientific echosounder system coupled with an ER60 software system (version 2.4.3). Two Simrad split-beam transducers, operating at 38 and 120 kHz, were mounted on a transducer pod located roughly 1.5 m starboard of the keel.

Calibration

The acoustic system was calibrated in the field before and after the survey. Calibration locations were chosen for survey logistics (e.g., offshore of Newport, Oregon) or for where the water beneath the ship was deep enough to avoid echo contamination from multipath effects and where the water column was, as much as possible, devoid of fish and other marine life (e.g., Elliott Bay, Seattle). Offshore of Newport, the *Shimada* drifted and used dynamic positioning; in Elliott Bay, the *Shimada* was anchored from the bow. The calibration procedure involved suspending one or more metal spheres with known backscattering cross-sections below the transducers and measuring the acoustic return following standard procedures (Simmonds and MacLennan 2005, Demer et al. 2015). On both the *Shimada* and the *Nordic Pearl*, a 38.1-mm tungsten carbide sphere with 6% cobalt binder was used for all transducers; the *Shimada* also used a 25-mm tungsten carbide sphere during a second calibration. Target strength and echo integration data were collected to calculate echosounder gain parameters to ensure the quality of system performance. On-axis and beam pattern data were recorded during the calibrations.

Operations

The *Shimada* maintained a vessel speed of approximately 11 knots (kn) during acoustic operations along each transect and up to 12 kn on cross-transects. The *Nordic Pearl* maintained a vessel speed of around 9 kn during survey operations. Running of acoustic transects occurred only between sunrise and sunset (i.e., roughly from 06:00 to 21:00 PDT, about 15 hours per day) when hake formed identifiable midwater layers, although acoustic data were collected day and night. Likewise, ADCP data were also collected day and night.

Acoustic data were collected from the transducer faces to a maximum depth of approximately 750 m for the EK60 system and 500 m for the EK80. Raw acoustic backscatter (ER60 .raw and ER80 .raw) data files were logged from all available frequencies. Acousticians used the raw files for live viewing and for scrutinizing on laptop PCs with Myriax Echoview software (version 8.0.76). Event log markers and other marks, including at-sea judgments of hake backscattering layers, were made on the live-viewed files. While all three EK60 frequencies were used for at-sea judgements, data from only the 38-kHz echosounder (the primary frequency used for generating biomass estimates) were post-processed for hake using Echoview, and results presented in this document are based on these data. (Data from the 120-kHz echosounder are being post-processed for euphausiids.)

Background noise was recorded in passive mode at frequent intervals either before the surveying of transects started in the morning or during cross-transects conducted offshore at depths greater than 1,500 m. These recordings were done to ensure the quality of the acoustic data and the consistency of system performance throughout the survey.

Intervessel calibration

To compare acoustic survey systems between the *Shimada* and the *Nordic Pearl*, both vessels conducted IVC operations off the northwest coast of Vancouver Island using a side-by-side design on multiple transects. The *Nordic Pearl* ran the acoustic transect while the *Shimada* paralleled the *Nordic Pearl*, separated by about 0.5 nmi, with the *Nordic Pearl* slightly ahead of the *Shimada*. Randomization was used to determine whether the *Shimada* was north or south of the *Nordic Pearl*. Given that the *Shimada* was offset from the transect by roughly a half-mile, only the acoustic data that the *Nordic Pearl* collected during the IVC were used for generating the hake biomass estimate. During the IVC, the *Nordic Pearl* conducted all fishing operations.

Biological Sampling

Equipment

Daytime trawling on fish sign observed by the *Shimada* was performed with an Aleutian wing trawl 24/20 (AWT). This net had a vertical opening that averaged 23 m (range: 19–30 m) and a headrope and footrope of 101.7 m each. A 1¼-inch (32-mm) codend liner was used. The AWT was deployed with a pair of 4-m^2, 884.5-kg "Fishbuster" trawl doors, 82.3-m legs, and 750-lb chain ("Tom") weights on each side. Rigging between the trawl doors and the headrope and footrope consisted of synthetic 18-mm TS-II rope. A Simrad FS70 third-wire trawl sonar was attached to an AWT headrope kite to monitor depth, net opening, and water temperature, and to gauge approximately the catch quantity.

Daytime trawling on fish sign observed by the *Nordic Pearl* was performed with an RS 250/550/14 midwater trawl (Cantrawl Pacific Fishing Services, Ltd.) rigged with 950-kg Thyboron Type-2 doors and 200-pound chain weights on each side. This trawl had 76.2-m long foot and head ropes with double side wings (three-point tow connection) along a 111.25-m side panel rope. The codend liner had a mesh of ¼ inch (6 mm). A Scanmar ScanBas trawl sonar was attached to the Cantrawl headrope to monitor and guide the fishing process for all trawls.

To provide additional biological ground-truthing (i.e., provide information on the biological composition of multiple scattering layers in the water column), the AWT was deployed on all trawls with a SpyTec Mobius camera and light system mounted to the top panel of the intermediate approximately 20 m forward of the codend. The camera faced aft and along the net toward the codend. Three custom pressure housings (made by Sexton Corporation) were mounted to a rigid ultra-high-molecular-weight polyethylene (UHMWPE) board. Two of the pressure housings held LED lights while the third held the camera. The housings with enclosed batteries used a pressure switch to activate lights and camera. The camera was programmed to start recording when external power was applied. Video data stored on a 32GB micro SD card in the camera were transferred to external storage shortly after each trawl was completed. Time, temperature, and pressure information collected from a Sea-Bird Electronics, Inc. SBE 39 temperature and pressure recorder clipped near the camera was overlaid onto the video files using a program written in-house with Python. Files were spliced together and trimmed to remove video prior to the lights switching on underwater and directly after the lights switched off. Review of the video was completed as soon as possible following a trawl and notes were recorded onto a spreadsheet.

Similarly, the Cantrawl on the *Nordic Pearl* was equipped with a digital video camera system mounted inside the net. This system had, however, a significantly different layout than the camera system used on the *Shimada*, and was used to assess the catch effectiveness of the net and behavior of organisms before they reached the trawl codend. This system consisted of a separate camera pressure housing and LED light pressure housing mounted in stainless steel frames tied directly to the inside of the net's top section. The lights were connected to an external battery pack housed in its own pressure cylinder. The frames were positioned at approximately 29 meters ahead of the codend section (which was 18 m long). The camera was facing down and toward the aft of the net, at an angle of approximately 30°. The light source was placed 1.5 m aft of the camera and was aimed directly downward, toward the bottom of the net. The camera used was a GoPro HERO4, while the pressure housing and lights were manufactured by A.G.O. Environmental Electronics, Ltd.

To verify the identity of acoustic targets suspected to be euphausiids (Euphausiacea) and/or lanternfish (Myctophidae) and to obtain specimens for species identification and length, a Methot trawl was deployed during daytime hours. The Methot consisted of a square metal frame (inner dimensions of 2.4 m by 2.4 m) to which an outer protective net (2.4 m by 2.4 m by 44 ft, with a 2-in mesh) and an inner net (1.4 m by 1.4 m by 43 feet, with a ⅛-in mesh) were attached. Samples were collected in a two-piece PVC collection bucket attached to the tail end of the inner net. To stabilize the Methot trawl during fishing, a 2.5-m wide V-shaped metal net depressor fin with a 75-lb ballast weight was attached. A Simrad integrated trawl instrumentation (ITI) sensor was attached to the frame to monitor depth in real time while fishing.

An electronic, 60-kg capacity Marel M1100 PL4200 motion-compensating scale was used to weigh sorted portions of the catch to the nearest 0.05 kg. A 15-kg capacity Marel M1100 PL2060 motion-compensating scale was used to determine weights of individual fish specimens to the nearest 0.002 kg. Individual fish lengths (fork length) were determined to the nearest centimeter with a Scantrol FM100 FishMeter board.

The *Shimada*'s flow-through system was used to collect water for analysis of the presence, distribution, and identification of harmful algal bloom (HAB) species and the toxins they produce. A 0.5-m vertical ring net with flowmeter and mesh size of 202 µm was used to conduct vertical zooplankton tows at predetermined sites.

Operations

Daytime trawling was used to classify observed backscatter layers to species and size composition and to collect specimens of hake and other organisms. The number and locations of trawls were not predetermined—other than an allowance for an expected total number of trawls by area based on available survey time—but depended on the occurrence and pattern of backscattering layers observed at the time of the survey. Coverage by trawling was adaptive: distinct layers of intense backscatter that were indicative of high densities of hake were the highest priority for trawl sampling. When possible, trawls were conducted at more than one location along any single, extensive, and continuous aggregation of hake, or within the same area where vertically discrete backscattering layers appeared. Other types of backscattering, both in terms of areas of low fish density and putative aggregations of species other than hake, were also sampled if observed.

Prior to commencing trawl operations, NWFSC marine mammal protocols were followed on the *Shimada* to ascertain whether any marine mammals were within 500 m for ten minutes prior to deploying gear. During trawl operations, trawling speed averaged about 3 kn (up to 2 kn for the Methot trawl). Individual trawls did not require a standardized effort. Instead, trawl durations varied, lasting only long enough to ensure that an adequate sample (i.e., a minimum of approximately 350 hake) was obtained. The scientist overseeing trawl operations determined the trawl duration based on the quantity of fish and other organisms that the trawl sonar observed entering the net.

Trawl catches on the *Shimada* were sorted and weighed completely. Total weights and numbers were determined for most species; gelatinous invertebrates such as jellyfish and salps often could not be counted because trawling frequently broke them apart. Hake were subsampled to determine length composition by sex (about 300 random samples per trawl) and to collect otoliths for subsequent age determination (about 50 samples per trawl, which also included collecting individual weights and lengths). When fewer than 350 hake were caught, they were sampled completely. Hake sexual maturity was determined by visual inspection of gonads and classified by a five-stage scale. Otoliths were preserved in 50% ethanol for subsequent age determination. Hake stomachs (roughly five per trawl) and ovaries were collected and preserved in 10% neutral-buffered formalin. Hake fin clips (up to 48 per trawl) were collected for genetic analysis. Widow rockfish (*Sebastes entomelas*) and yellowtail rockfish (*S. flavidus*) were subsampled when caught.

Zooplankton sampling with a vertical ring net was conducted along Transects 1 (Point Conception), 24 (Bodega Bay), 40 (Trinidad Head), 62 (north of the Newport Hydroline), 98 (North West Coast Vancouver Island), and between 87 and 89 (south of the West Coast Vancouver Island Mackas Line). Six stations per transect were completed at bottom depths of 60–70 m, 150 m, 300 m, 500 m, 1,000 m, and 1,500 m. The net was towed vertically while the *Shimada* held station. A target depth of 100 m was used when bottom depths were greater than 100 m; when bottom depths were shallower than 100 m, a target depth of 2–5 m off bottom was used. Zooplankton samples were stored in formalin and analyzed back on land.

Oceanographic Sampling

Equipment

Vertical profiles of temperature and salinity data were collected using a rosette-mounted Sea-Bird SBE 911plus CTD (conductivity–temperature–depth) system; the *Shimada* also had an Oceanscience UnderwayCTD (uCTD) that could be deployed while the vessel was underway. On the *Shimada*, in conjunction with the CTD casts, vertical profiles of dissolved oxygen (DO) were collected using a Sea-Bird SBE 43 DO sensor that was attached to the SBE 911plus CTD. Additional oceanographic data were collected by attaching Sea-Bird SBE 39 temperature and pressure recorders to the AWT headrope kite and underwater camera system during trawls. Sea surface temperature and salinity data were collected using a Sea-Bird SBE probe located below the vessel's waterline in the *Shimada*'s flow-through system. On the *Nordic Pearl*, profiles of temperature, salinity, and dissolved oxygen concentration were collected on all trawls from a net-mounted CTD (RBR, Ltd. Concerto3 model). This logger was affixed to the starboard trawl ribline, adjacent to the trawl camera.

Operations

Physical oceanographic sampling was conducted day and night on the *Shimada*. CTD casts were performed at night at predetermined locations, in conjunction with zooplankton sampling stations, and when the acoustic system was calibrated. Underway CTD casts were conducted at predetermined stations during daytime while the ship was collecting acoustic data, but only if sea conditions were favorable for safely deploying the uCTD probe. When deploying uCTDs, the *Shimada* slowed down to about 6 kn. The *Shimada*'s Scientific Computer System (SCS) collected sea surface data (e.g., temperature and salinity) continuously day and night throughout the entire survey.

Results

Acoustic System Calibration

The first calibration of the *Shimada*'s EK60 acoustic system was conducted on 19 June offshore of Newport; the second was conducted on 12 September in Elliott Bay. Results of both calibrations of the EK60 (Table 2) were within expected levels based on factory settings and results from previous calibrations. The EK80 system was calibrated once, in Elliott Bay; its calibration also was successful. The *Nordic Pearl's* acoustic system was calibrated on 14 August and 10 September just outside of Departure Bay, Nanaimo. Results of the calibrations were also within expected levels based on factory settings and results from previous calibrations.

Acoustic Sampling and Pacific Hake Distribution

The *Shimada* collected acoustic data from 102 transects (Table 3) between lat 34.5°N and 54.8°N for a linear distance of 3,684 nmi; the *Nordic Pearl* collected acoustic data from 37 transects (Table 4) between lat 47.8°N and 54.8°N for a linear distance of 1,659 nmi. Mechanical issues and a temporary crew member shortage caused the *Shimada* to lose eleven survey days. To make up for this lost time at sea, the *Shimada* dropped 13 transects. Although a small portion of transect 88 was run (roughly 17 nmi), the acoustic data collected on this transect were not used for the hake biomass estimate and this transect was included in the 13 that were dropped. The *Nordic Pearl* dropped two transects.

Four transects in U.S. waters (27, 28, 40, and 41) were extended further west to map the offshore extent of hake sign; total linear distance of the extensions was roughly 36 nmi. All four extended transects were off the coast of Northern California between Crescent City and San Francisco.

Adult hake were observed on 91 transects, with aggregations detected from just north of Morro Bay on Transect 7 (Figure 2) to Hecate Strait on Transect 114. Off the U.S. coast, the highest concentrations of hake were observed between San Francisco and Newport, with markedly extensive aggregations of hake observed on Transects 27–29 near Point Arena. Hake sign south of San Francisco was relatively light or absent. North of Newport along the Oregon and Washington coasts, hake were observed fairly consistently, but aggregations were relatively light. One very strong aggregation of hake was observed near the entrance to the Strait of Juan de Fuca. In Canadian waters, the highest concentrations of hake were observed along the northern half of Vancouver Island. Further north, only a handful of modest hake aggregations were observed in Queen Charlotte Sound, but a cluster of hake spanning seven transects (108–114) was observed in Hecate Strait. Dixon Entrance, Southeast Alaska, and most of the waters around the Haida Gwaii Islands had no hake.

Intervessel Calibration

The IVC was conducted between the *Shimada* and the *Nordic Pearl* on 20 August and between 22–23 August. The vessels covered six transects at the northern end of Vancouver Island (90, 95–99), plus added a pair of diagonal transects (1096 and 1098) that were not used in generating the hake biomass estimate. Total linear distance covered was 223 nmi (175 nmi of east–west transects plus 48 nmi of diagonal transects). The resulting acoustic backscatter (NASC) at 38 kHz did not differ markedly between the two vessels.

Biological Sampling

Sixty-eight (68) midwater trawls (51 by the *Shimada* and 17 by the *Nordic Pearl*) were successfully conducted during the survey (Figure 3, Tables 5 and 6). Average trawl duration on the *Shimada* was 18.6 minutes (range: 0.3–40.7) and average trawl depth was 257 m (range: 107–441). On the *Nordic Pearl*, average trawl duration and target depth were 16.3 minutes (range: 2.3–38.3) and 195 m (range: 95–400), respectively. On the *Shimada*, one trawl (on Transect 7) was aborted before deployment of gear because there were marine mammals within 500 m of the vessel. Six other trawls were aborted because of either gear or deployment issues. No trawls were aborted on the *Nordic Pearl*.

Of the 51 trawls that the *Shimada* conducted, 46 (90%) caught hake, including two trawls (30 and 47) that caught roughly 3.7 kg (n = 515) of young-of-the-year (i.e., age-0) hake. Of the seven trawls that the *Shimada* conducted in Canadian waters (48–57), only two caught hake. Overall, hake catch weights ranged from 0.3 kg to 2,123.2 kg, with an average of 311 kg; nonhake catch weights ranged from 0.5 kg to 4,023.1 kg, with an average of 105 kg. Of the 17 trawls that the *Nordic Pearl* conducted, 14 (82%) caught hake. Hake catch weights ranged from 6.7 kg to a little over 11,700 kg; most trawls caught less than 1,000 kg of hake.

The *Shimada* conducted 13 successful Methot trawls (Table 7), all but two of which were in Canadian waters. Average duration was 17.3 minutes and average gear depth was 168 m.

Hake was the dominant species caught in the 44 trawls that the *Shimada* conducted in U.S. waters, accounting for 73% of catch composition by weight (Table 8); the next 20% was composed of widow rockfish, 99% of which came from just one trawl off Astoria, Oregon (Trawl 39). By number, hake (including young-of-the-year) accounted for over 68% of catch composition. Although sea pickles (*Pyrosoma* spp.) and sea tongues (*P. atlanticum*) combined accounted for only 1.7% of catch composition by weight, they were 18% of catch composition by number, reflecting a dramatic population increase of these species in 2017 (Brodeur et al. 2018). In the seven trawls that the *Shimada* conducted in Canadian waters (Table 9), far more Pacific herring (*Clupea pallasi*) were caught than any other species. Catch composition of trawls that the *Nordic Pearl* conducted, both in U.S. waters (Table 10) and in Canadian waters (Table 11), was dominated by hake.

Between the *Shimada* and the *Nordic Pearl*, 14,980 hake were measured for length and 2,749 pairs of hake otoliths were collected (Tables 12 and 13). Over 1,600 hake fin clips were collected on the *Shimada* as well. Raw length–frequency distributions (Figure 4) were characterized by U.S. hake displaying strong modes at 27 cm (age-1 hake) and 38 cm (age-3 hake), with age-0 hake at 10–11 cm. Hake in Canada consisted proportionally of far more larger fish (i.e., >40-cm) than fish smaller than 30 cm, although a mode of age-0 hake was observed as well. Hake specimens collected during the survey ranged in age from 1 to 20 years (Figure 5); dominant ages observed were one, three, and seven years.

Pacific Hake Abundance Estimate

The 2017 biomass estimate of adult hake (age-2+) off the U.S. and Canada west coast totaled 1.418 million metric tons (Figure 6), with approximately 73% (1.028 Mt) of observed biomass located in U.S. waters. Even though it represented a decrease of roughly 34% from the 2015 biomass estimate, 2017's estimate was very close to an average for all surveys conducted since 1995 (1.418 vs. 1.432). Age-3 and age-7 hake contributed most to the 2017 biomass estimate (Figure 7). While the 2014 year class was roughly 53% larger than the 2010 year class and more than twice as numerous, when combined, these two year classes amounted to 73% of the total surveywide observed biomass and 79% of observed numbers.

Oceanographic Sampling

Zooplankton samples were collected at 36 stations (Figure 8). Three hundred twenty (320) CTD temperature and salinity profiles were collected by the *Shimada* at selected locations along the line transects and at both acoustic system calibration sites; 152 uCTD profiles were successfully collected (17 failed). Additional temperature profiles were collected from 125 successful SBE 39 casts (54 with the AWT headrope kite, 56 with the AWT camera system, and 15 with the Methot trawl, including test trawls). Also, 400 HAB samples were collected. The *Nordic Pearl* collected CTD profiles at the Departure Bay calibration site and at all trawl stations.

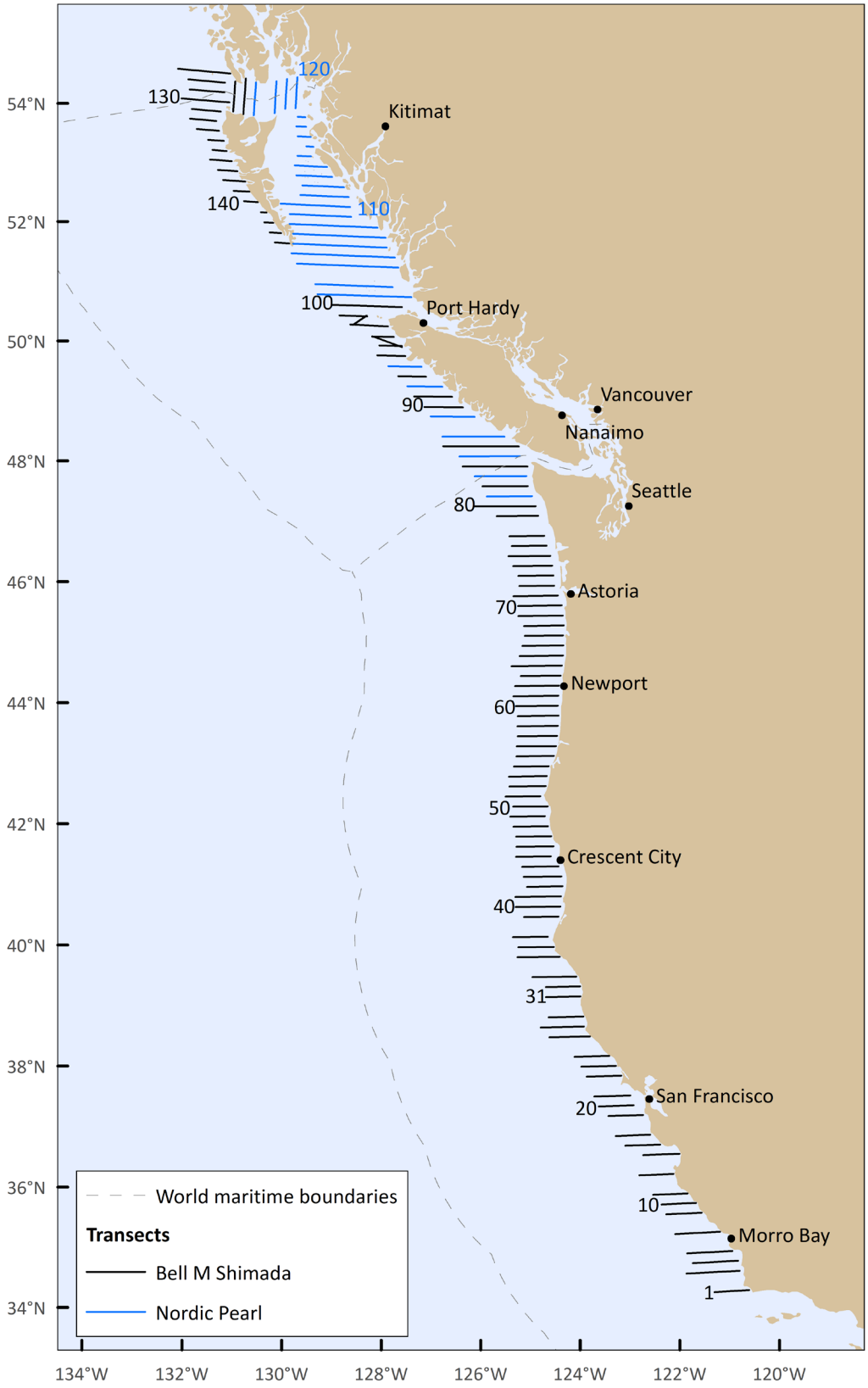

Figure 1. Survey track design used during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

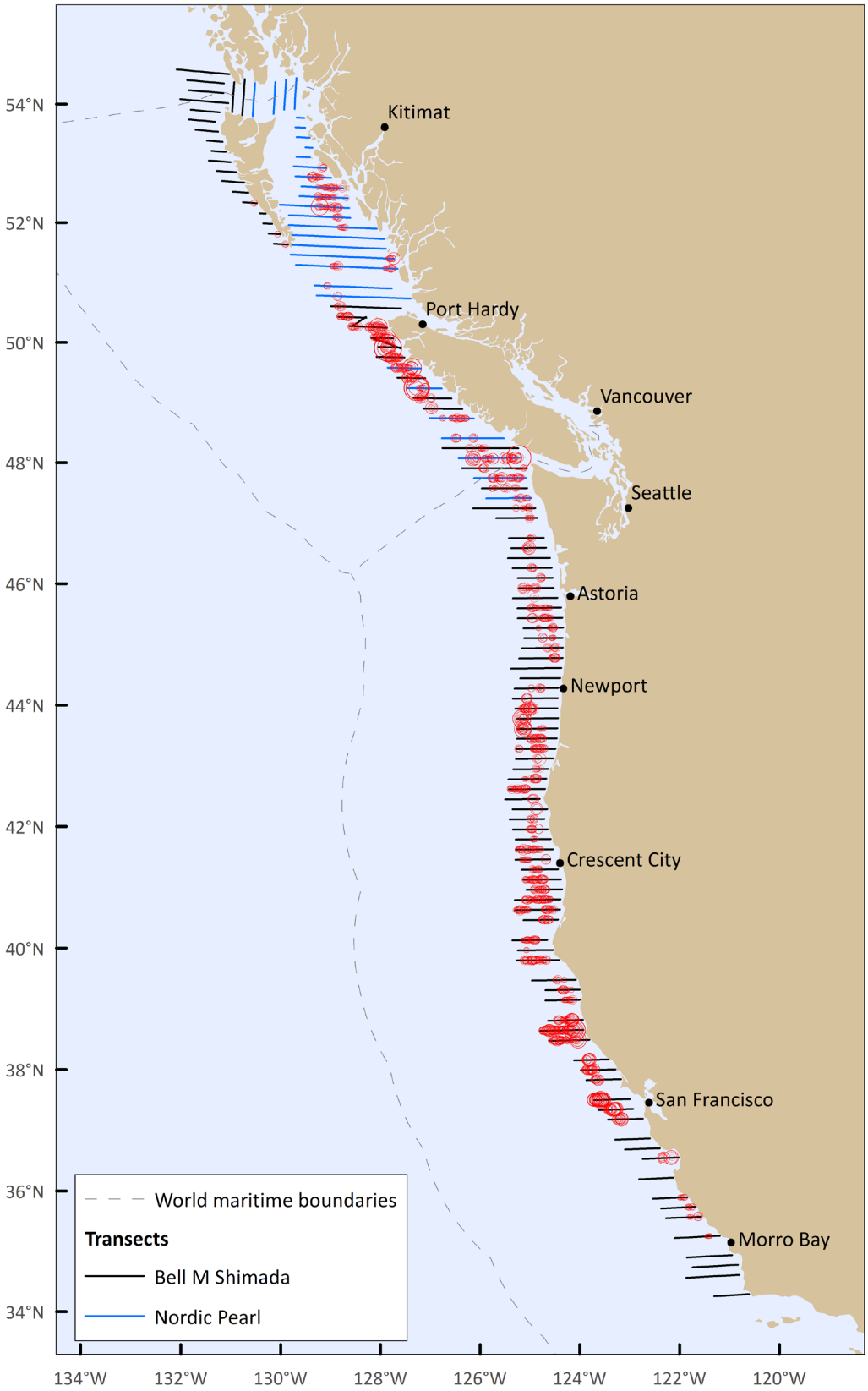

Figure 2. Acoustic area backscattering attributed to adult (age-2+) Pacific hake along transects completed during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

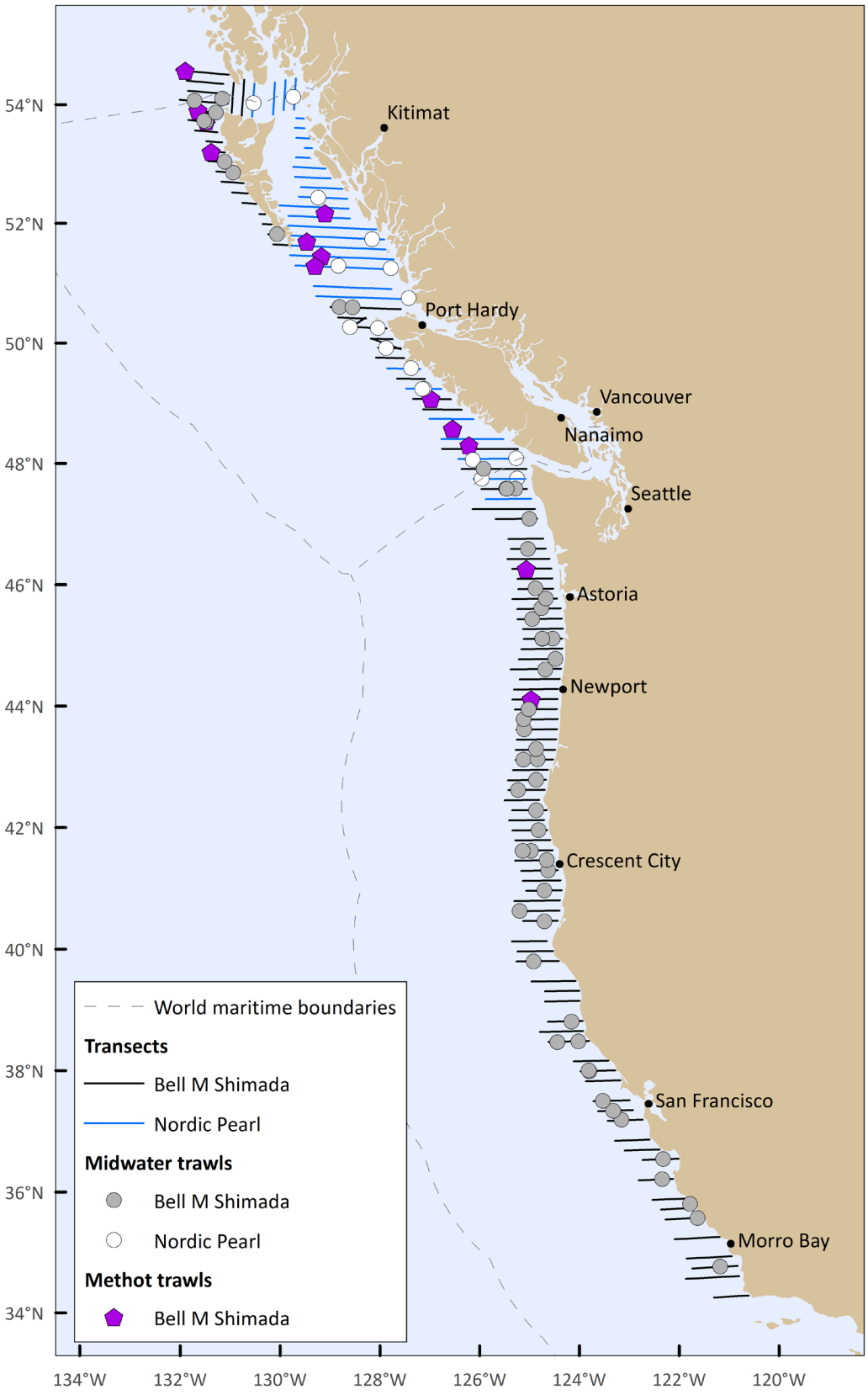

Figure 3. Acoustic transect lines and locations of midwater trawls and Methot trawls conducted during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

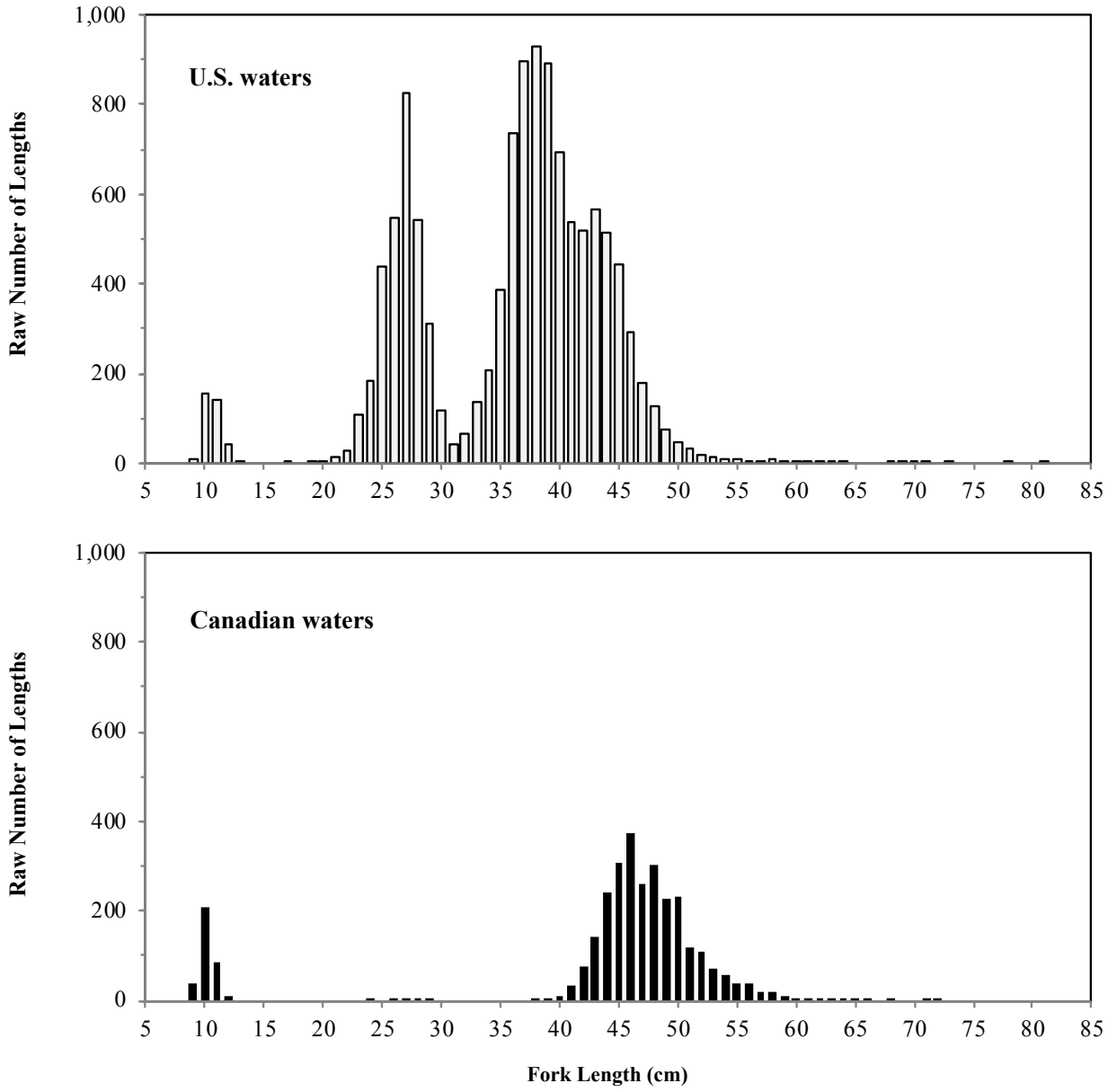

Figure 4. Raw length–frequency distributions of Pacific hake from specimens measured during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

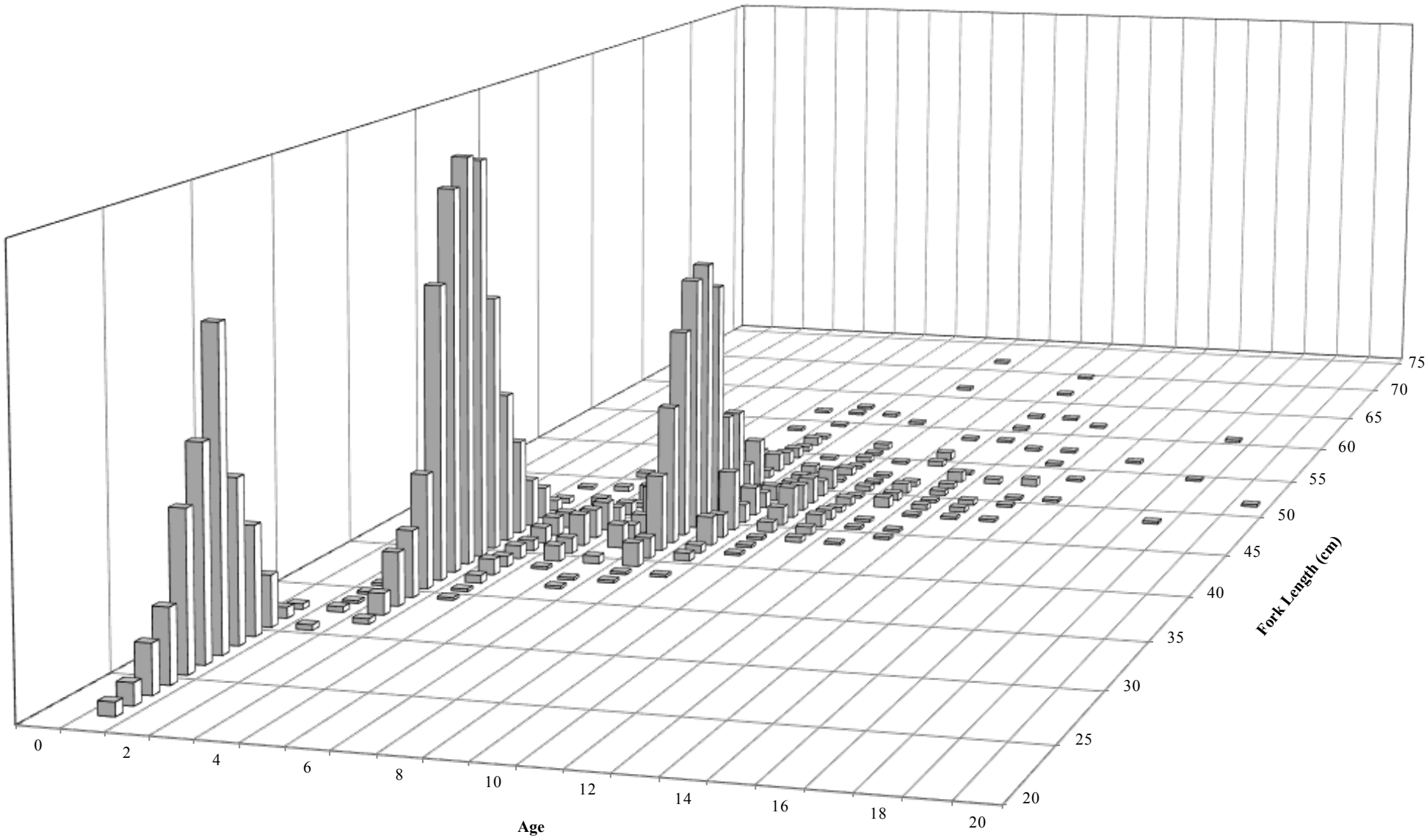

Figure 5. Age–length distribution of Pacific hake from specimens collected during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey. Ages are based on interpretation of otoliths.

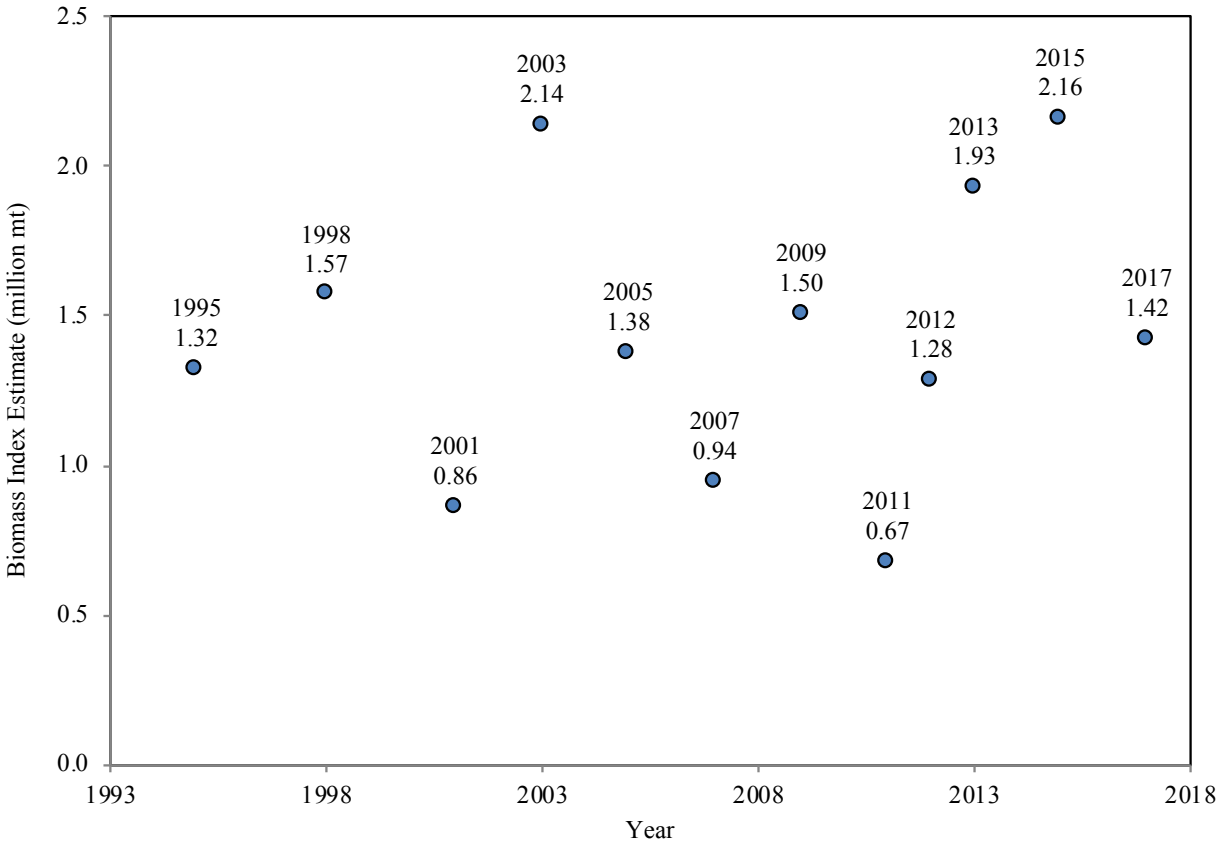

Figure 6. Coastwide biomass estimates (millions of metric tons) of adult Pacific hake (age-2+) from joint U.S. and Canada integrated acoustic and trawl surveys, 1995–2017. Each symbol displays survey year and biomass estimate. Historical biomass estimates (1995–2013) were reanalyzed in 2015 and may be different from those in previous reports.

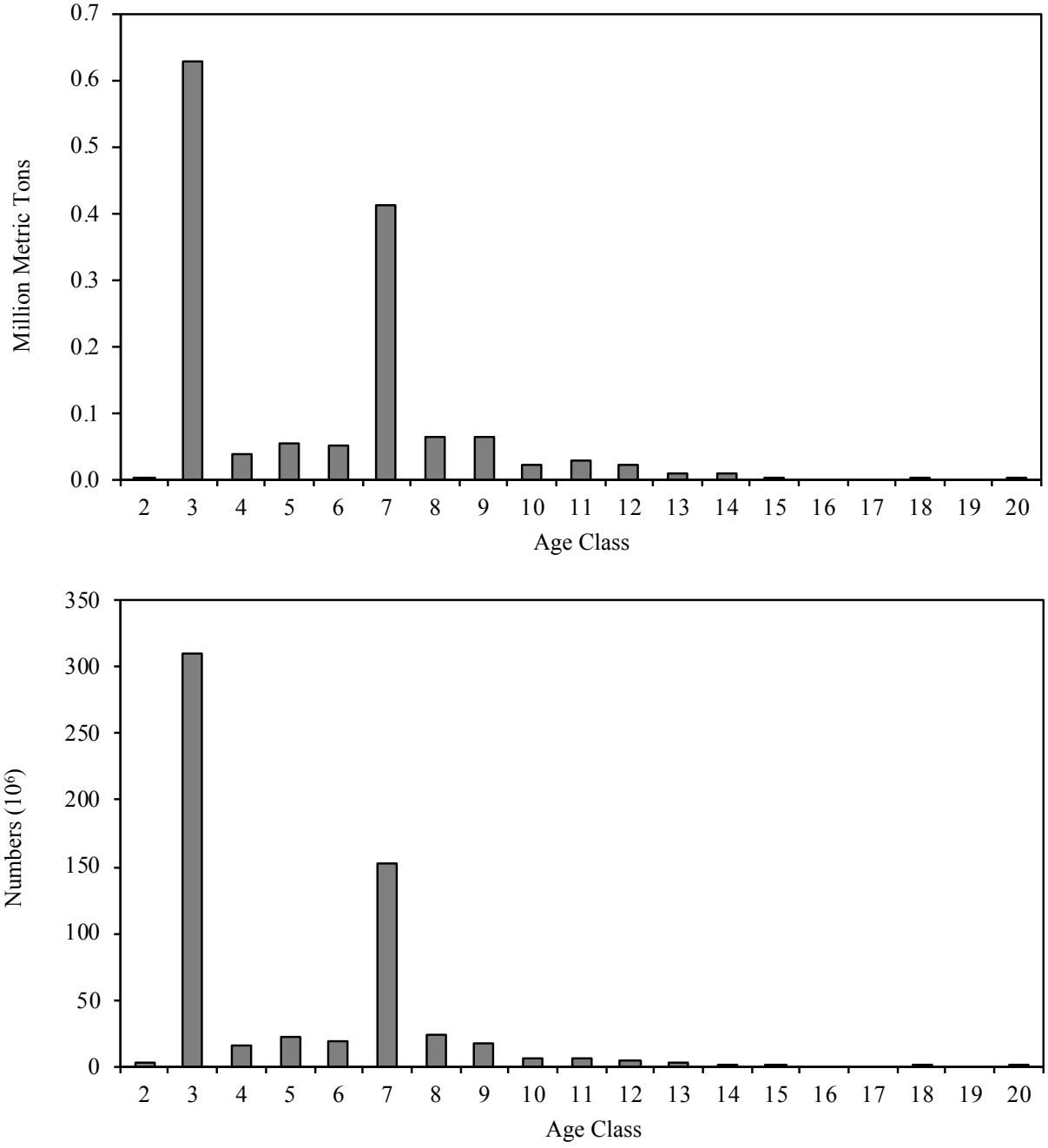

Figure 7. Acoustically weighted estimated biomass (millions of metric tons) and numbers (10^6) of adult Pacific hake by age class from the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

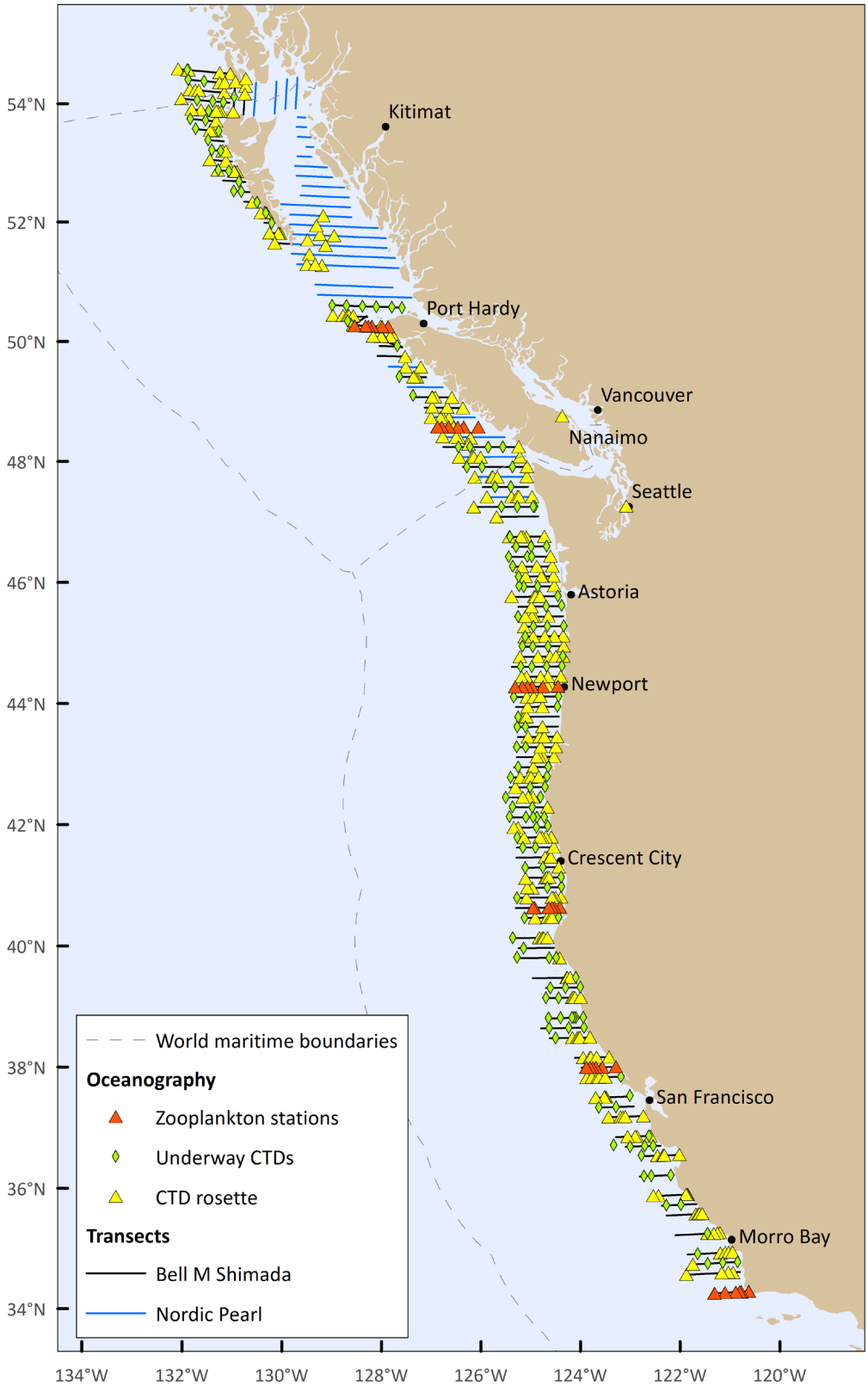

Figure 8. Acoustic transect lines with locations of zooplankton stations, conductivity-temperature-depth (CTD) rosette deployments, and underway CTDs conducted by the NOAA Ship *Bell M. Shimada* and the FV *Nordic Pearl* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

Table 1. Itinerary for the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

Country	Leg	Date(s)	Notes
U.S.	1	06/13–14	Personnel embark onto the NOAA Ship *Bell M. Shimada* in Newport (OR).
		06/16–21	The planned departure is delayed six days because of mechanical issues with the Shimada's generators.
		06/19	Personnel conduct an acoustic system calibration of the *Shimada* with standard targets while drifting and using dynamic positioning offshore of Newport.
		06/22	The *Shimada* leaves Newport and starts transiting south.
		06/25	The survey starts with Transect 1 at Point Conception (CA).
		06/30	The *Shimada* finishes Transect 16.
		07/01–04	Inport San Francisco (CA); exchange personnel.
U.S.	2	07/05	The *Shimada* leaves San Francisco and resumes the survey with Transect 17.
		07/19	The *Shimada* finishes Transect 49; starts transit to Newport.
		07/20–22	Inport Newport; exchange personnel.
U.S.	3	07/23	The planned departure is delayed one day because of a ship's staffing shortage.
		07/24	The *Shimada* leaves Newport.
		07/25	The *Shimada* resumes the survey with Transect 50.
		08/06	The *Shimada* finishes Transect 75; starts transit to Newport.
		08/07–10	Inport Newport; exchange personnel.
U.S.	4	08/11–13	The planned departure is delayed three days because of mechanical issues with the *Shimada*'s generators.
		08/14	The *Shimada* leaves Newport.
		08/15	The *Shimada* resumes the survey with Transect 76.
		08/20	The *Shimada* and the FV *Nordic Pearl* conduct an intervessel calibration on one transect (90).
		08/22–23	At Transect 95, the *Shimada* and *Nordic Pearl* resume conducting IVC operations, which continue north through Transect 99.
		08/25	The *Shimada* finishes Transect 100; starts transit to Port Angeles (WA).
		08/26–28	Inport Port Angeles; exchange personnel.
U.S.	5	08/29	The *Shimada* leaves Port Angeles.
		08/31	The *Shimada* resumes the survey with Transect 144.
		09/01	A ribline on one of the AWTs (#5594) snaps during retrieval, retiring the net for the rest of the survey.
		09/05	The trawl warp on the port door parts after haul back. The net and catch are retrieved, but AWT fishing operations are suspended for the remainder of the survey.
		09/07	The *Shimada* finishes Transect 125; starts transit to Hecate Strait to look for euphausiids for Methot trawling.
		09/12	Personnel conduct an acoustic system calibration of the *Shimada* with standard targets in Elliott Bay, Seattle.
		09/13	Inport Seattle; personnel disembark.

Table 1 (continued). Itinerary.

Country	Leg	Date(s)	Notes
Canada	1	08/14	Personnel conduct an acoustic system calibration of the *Nordic Pearl* with standard targets just outside of Departure Bay, Nanaimo (BC).
		08/15	The planned departure of the *Nordic Pearl* is delayed one day for delivery of a generator required for fishing operations.
		08/16	The *Nordic Pearl* leaves Nanaimo and transits to the Washington coast.
		08/17	The *Nordic Pearl* starts surveying with Transect 81.
		08/20	The *Nordic Pearl* and *Shimada* conduct an intervessel calibration on one transect (90).
		08/22–23	At Transect 95, the *Nordic Pearl* and *Shimada* resume conducting IVC operations, which continue north through Transect 99.
		08/24–28	The *Nordic Pearl* completes surveying the north end of Vancouver Island and proceeds into Hecate Strait, then transits to Port Hardy (BC).
Canada	2	08/29	Science crew change in Port Hardy; the *Nordic Pearl* transits to the inside of Haida Gwaii.
		08/30–09/04	The *Nordic Pearl* conducts acoustic surveying in Hecate Strait.
		09/04–06	The *Nordic Pearl* conducts acoustic surveying in Dixon Entrance; refuels in Prince Rupert (BC).
		09/07–08	The *Nordic Pearl* transits to the west coast of Vancouver Island.
		09/09	The *Nordic Pearl* collects acoustic and mooring equipment in Ucluelet (BC), then transits to Clayoquot Canyon and Barkley Canyon for deployments of subsurface moorings.
		09/10	The *Nordic Pearl* transits to Nanaimo; personnel conduct an acoustic system calibration with standard targets just outside of Departure Bay.
		09/11	Inport Nanaimo; personnel disembark.

Table 2. Simrad ER60 38-kHz acoustic system descriptions and settings used aboard the NOAA Ship *Bell M. Shimada* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey, and results from acoustic system calibrations with standard targets. Key: $Sa = 10\log_{10}$ (area scattering coefficient), S_v = volume backscattering, *TS* = target strength.

			Calibrations	
		Survey system settings	**06/19 Newport (OR)**	**09/12 Elliott Bay (WA)**
Transducer		ES38B	—	—
Serial number		30715	—	—
Transducer depth (m)		9.15	—	—
Pulse length (ms)		1.024	—	—
Transmitted power (W)		2,000	—	—
Angle sensitivity		21.97	—	—
Two-way beam angle (dB)		-21.01	—	—
Sa correction (dB)		-0.52	-0.52	-0.55
S_v gain (dB)		25.55	25.55	25.79
TS gain (dB)		26.07	26.07	26.34
3-dB beamwidth (deg.)	Along (minor)	6.81	6.81	6.88
	Athwart (major)	6.85	6.85	6.87
Angle offset (deg.)	Along (minor)	-0.08	-0.08	-0.05
	Athwart (major)	0.00	0.00	-0.03
Postprocessing S_v threshold (dB)		-69	—	—
Sphere range from transducer (m)		—	28.63	18.47
Absorption coefficient (dB/m)		0.009855	0.008801	0.007884
Sound velocity (m/s)		1,480.6	1,492.8	1,498.3
Water temperature at transducer (°C)		—	13.7	13.2
Water temperature at sphere (°C)		—	9.1	13.0

Table 3. Coordinates (decimal degrees) and lengths of transects conducted by the NOAA Ship *Bell M. Shimada* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

	Start		End		
Transect	**Latitude (°N)**	**Longitude (°W)**	**Latitude (°N)**	**Longitude (°W)**	**Length (nmi)**
1	34.4896	121.2447	34.4900	120.5340	35.1
2		dropped			
3	34.8232	121.7976	34.8228	120.7104	53.5
4	34.9896	120.7258	34.9895	121.6549	45.7
5	35.1563	120.8349	35.1567	121.7597	45.4
6		dropped			
7	35.4895	121.9881	35.4897	121.0652	45.1
8		dropped			
9	35.8235	121.4185	35.8232	122.1551	35.8
10	35.9900	122.2457	35.9899	121.5276	34.9
11	36.1570	122.4151	36.1563	121.6912	35.1
12		dropped			
13	36.4897	121.9695	36.4898	122.6820	34.4
14		dropped			
15	36.8228	121.8281	36.8228	122.5895	36.6
16	36.9896	122.9567	36.9897	122.2247	35.1
17	37.1568	122.4200	37.1559	123.1529	35.0
18		dropped			
19	37.4900	122.5569	37.4896	123.2916	35.0
20	37.6565	123.4913	37.6568	122.7539	35.0
21	37.8236	123.5814	37.8229	122.8150	36.3
22		dropped			
23	38.1568	122.9889	38.1559	123.7297	34.9
24	38.3236	123.0972	38.3227	123.8404	35.0
25	38.4901	123.2412	38.4898	123.9849	34.9
26		dropped			
27	38.8232	124.5194	38.8231	123.6439	40.9
28	38.9898	123.7620	38.9892	124.7000	43.7
29	39.1564	123.7712	39.1552	124.5234	35.0
30		dropped			
31	39.4901	123.8233	39.4897	124.5796	35.0
32	39.6565	124.5741	39.6564	123.8269	34.5
33	39.8231	123.9039	39.8236	124.8687	44.5
34		dropped			
35	40.1576	124.2598	40.1563	125.1912	42.7
36	40.3232	125.1711	40.3235	124.3868	35.9
37	40.4899	124.5178	40.4899	125.2881	35.2
38		dropped			
39	40.8233	125.0406	40.8227	124.2698	35.0
40	40.9897	124.2238	40.9899	125.2270	45.4
41	41.1569	125.2293	41.1563	124.2081	46.1
42	41.3232	124.9636	41.3231	124.1661	35.9
43	41.4898	124.1895	41.4898	125.0329	37.9

Table 3 (continued). Coordinates (decimal degrees) and lengths of transects conducted by the *Shimada*.

	Start			End		
Transect	**Latitude (°N)**	**Longitude (°W)**		**Latitude (°N)**	**Longitude (°W)**	**Length (nmi)**
44	41.6566	124.2482		41.6563	125.0695	36.8
45	41.8230	125.2030		41.8233	124.4194	35.0
46	41.9900	124.3493		41.9899	125.1933	37.6
47	42.1572	125.1941		42.1568	124.3969	35.5
48	42.3229	125.2569		42.3236	124.4682	35.0
49	42.4905	124.5371		42.4903	125.3299	35.1
50	42.6558	124.4688		42.6565	125.2608	34.9
51	42.8231	125.4301		42.8233	124.6343	35.0
52	42.9902	124.5103		42.9892	125.3436	36.6
53	43.1561	125.3494		43.1567	124.4772	38.2
54	43.3233	124.4313		43.3233	125.2328	35.0
55	43.4900	125.1718		43.4906	124.3063	37.7
56	43.6508	124.2547		43.6569	125.1628	39.4
57	43.8230	125.1402		43.8232	124.2223	39.7
58	43.9911	124.1995		43.9902	125.1456	40.8
59	44.1567	125.1341		44.1562	124.1785	41.1
60	44.3229	124.1899		44.3246	125.1774	42.4
61	44.4896	125.2334		44.4895	124.1724	45.4
62	44.6563	124.1513		44.6559	125.1882	44.3
63	44.8235	125.0548		44.8226	124.1087	40.3
64	44.9907	125.2677		44.9895	124.0768	50.5
65	45.1559	124.0413		45.1566	125.0744	43.7
66	45.3234	124.0296		45.3231	125.0056	41.2
67	45.4900	124.9484		45.4898	124.0308	38.6
68	45.6568	124.9630		45.6567	124.0114	39.9
69	45.8230	124.0270		45.8230	125.0988	44.8
70	45.9897	125.0987		45.9899	124.0489	43.8
71	46.1561	124.1340		46.1564	125.2115	44.8
72	46.3233	124.2252		46.3229	125.0677	34.9
73	46.4901	125.0844		46.4895	124.2360	35.0
74	46.6563	124.2601		46.6564	125.2125	39.2
75	46.8231	125.3236		46.8223	124.2990	42.1
76	46.9896	124.3871		46.9900	125.2421	35.0
77	47.1565	125.2969		47.1565	124.4390	35.0
78			dropped			
79	47.4897	125.6088		47.4898	124.5844	41.5
80	47.6545	124.6409		47.6560	126.1734	61.9
82	47.9886	124.8284		47.9891	125.9580	45.4
84	48.3206	124.8278		48.3233	126.4534	64.9
86	48.6566	125.0432		48.6584	126.9467	75.4
88[a]	48.9898	127.0976		48.9896	126.6559	17.4
90[b]	49.3148	127.4410		49.3141	126.4584	38.4
91	49.4903	126.7350		49.4881	127.7008	37.6

[a] Transect 88 was not used for the hake biomass estimate because the *Shimada* completed only a portion of it.
[b] The IVC transects that the *Shimada* completed were not used for the hake biomass estimate.

Table 3 (continued). Coordinates (decimal degrees) and lengths of transects conducted by the *Shimada*.

	Start		End		
Transect	**Latitude (°N)**	**Longitude (°W)**	**Latitude (°N)**	**Longitude (°W)**	**Length (nmi)**
93	49.8234	128.1245	49.8230	127.4084	27.7
95[b]	50.1654	127.9533	50.1654	128.6731	27.7
96[b]	50.3336	128.6265	50.3315	128.0399	22.5
1096[b]	50.3147	128.0394	50.4821	128.8200	31.5
97[b]	50.4805	128.8220	50.4814	128.2637	21.3
98[b]	50.6564	128.4196	50.6678	129.4057	37.5
1098[b]	50.6629	129.3377	50.8272	128.9822	16.7
99[b]	50.8143	128.9697	50.8144	129.6963	27.5
100	50.9890	129.9015	50.9891	128.0666	69.3
125	54.1405	132.5856	54.7553	132.5846	36.9
126	54.6889	132.8737	54.1736	132.8719	30.9
127	54.8232	134.5076	54.8224	133.0313	51.0
128	54.6564	133.1590	54.6573	134.1900	35.8
129	54.4898	134.1243	54.4898	133.1557	33.8
130	54.3226	132.9971	54.3234	134.3299	46.6
131	54.1566	134.0197	54.1567	133.2151	28.3
132	53.9899	134.0495	53.9897	133.3184	25.8
133	53.8230	133.2162	53.8229	133.8380	22.0
134	53.6568	133.5040	53.6563	133.0643	15.6
135	53.4895	132.9660	53.4893	133.3559	13.9
136	53.3234	133.4026	53.3231	132.8054	21.4
137	53.1563	133.1616	53.1566	132.6288	19.2
138	52.9902	132.4026	52.9900	133.0024	21.7
139	52.8232	132.6944	52.8230	132.2680	15.5
140	52.6562	132.0224	52.6571	132.3925	13.5
141	52.4902	131.7696	52.4898	131.9204	5.5
142	52.3237	131.5756	52.3235	131.8126	8.7
143	52.1568	131.3455	52.1569	131.6535	11.3
144	51.9899	131.4978	51.9893	131.1131	14.2

[b] The IVC transects that the *Shimada* completed were not used for the hake biomass estimate.

Table 4. Coordinates (decimal degrees) and lengths of transects conducted by the Canadian FV *Nordic Pearl* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

	Start		End		
Transect	**Latitude (°N)**	**Longitude (°W)**	**Latitude (°N)**	**Longitude (°W)**	**Length (nmi)**
81	47.8224	124.7283	47.8226	125.8482	45.1
83	48.1572	126.1547	48.1582	124.8604	51.8
85	48.4932	125.0192	48.4899	126.5396	60.5
87	48.8227	126.9673	48.8233	125.4030	61.8
89	49.1568	126.1581	49.1563	127.2722	43.7
90	49.3240	127.4419	49.3236	126.4591	38.4
92	49.6566	126.9828	49.6562	127.8830	35.0
94	49.9900	127.5295	49.9882	128.3798	32.8
95	50.1563	127.9524	50.1591	128.6838	28.1
96	50.3233	128.6275	50.3234	128.0406	22.5
1096[a]	50.3235	128.0428	50.4920	128.8254	31.6
97	50.4907	128.8185	50.4899	128.2625	21.2
98	50.6562	128.4008	50.6570	129.3842	37.4
1098[a]	50.6559	129.3238	50.8227	128.9702	16.7
99	50.8228	128.9804	50.8235	129.6994	27.3
101	51.1569	127.8262	51.1563	130.2903	92.7
102	51.3239	130.3694	51.3232	128.3267	76.6
103			dropped		
104	51.6567	128.1818	51.6563	130.8808	100.5
105	51.8233	131.0372	51.8237	128.2809	102.2
106	51.9898	128.5105	51.9900	131.0071	92.2
107	52.1566	131.0197	52.1572	128.5498	90.9
108	52.3235	128.7706	52.3230	131.1298	86.5
109	52.4897	131.1407	52.4895	129.4884	60.4
110	52.6566	129.5298	52.6567	131.4009	68.1
111	52.8233	130.8862	52.8239	129.5784	47.4
112	52.9903	129.7155	52.9898	130.8500	41.0
113	53.1566	131.0208	53.1569	130.0495	34.9
114	53.3234	130.2025	53.3229	131.0827	31.5
115	53.4899	131.0242	53.4896	130.6499	13.4
116	53.6568	130.7977	53.6565	130.6038	6.9
117	53.8235	130.6874	53.8226	131.0472	12.7
118	53.9900	131.0941	53.9901	130.8319	9.3
119	54.1564	130.8654	54.1563	131.0791	7.5
120	54.2988	131.1510	54.8326	131.1507	32.0
121	54.7958	131.4370	54.2814	131.4363	30.9
122	54.1918	131.7259	54.7423	131.7257	33.0
123			dropped		
124	54.7015	132.2989	54.1323	132.2995	34.2

[a] The diagonal IVC transects (1096 and 1098) were not used for the hake biomass estimate.

Table 5. Station and catch data summary of midwater trawls conducted by the NOAA Ship *Bell M. Shimada* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

											Catch		
					Start position		Depth (m)		Temperature (°C)		Pacific hake		Other
Trawl	Transect	Date (DD/MM)	Time (PDT)	Duration (min.)[a]	Lat. (°N)	Long. (°W)	Gear[b]	Bottom	Gear[c]	Surface	(kg)	Number	(kg)
1	4	26/06	16:22	31.2	34.9913	121.0798	273	520	8.72	14.68	36.8	331	0.8
2	9	28/06	07:47	19.4	35.8197	121.4932	185	284	9.08	12.12	542.9	2,811	1.9
3	10/11	28/06	18:41	17.9	36.0583	121.6358	200	444	8.96	11.72	720.2	4,367	0.5
4	13	29/06	14:39	21.2	36.4908	122.1897	157	>750	9.16	13.36	1,134.9	8,155	28.5
5	15	30/06	09:06	3.1	36.8203	122.1532	158	271	9.13	11.66	1,737.0	2,930	37.7
6	19	06/07	09:19	20.3	37.4988	122.9963	257	303	7.98	15.11	1.5	2	1.2
7	20	06/07	16:23	21.2	37.6505	123.1688	370	1,051	7.45	14.84	8.4	21	5.6
8	21	07/07	08:44	31.5	37.8213	123.3785	338	455	7.71	11.15	477.8	1,218	2.9
9	24	08/07	13:49	36.1	38.3155	123.6480	310	964	7.31	11.95	7.7	23	13.8
10	24	08/07	16:16	36.1	38.3297	123.6627	374	1,063	6.98	12.04	519.9	1,471	11.4
11	27	09/07	16:53	trawl aborted because of gear issues							—	—	—
12	27	09/07	18:46	37.1	38.8100	124.3230	338	>1,700	6.91	11.99	169.7	364	16.6
13	27	10/07	09:11	6.0	38.8138	123.8727	249	256	8.46	11.74	341.4	823	1.6
14	29	11/07	15:05	18.5	39.1445	124.0088	195	479	8.25	11.47	333.1	900	17.4
15	35	13/07	09:54	32.9	40.1532	124.8165	217	926	7.65	10.75	240.9	628	8.5
16	39	14/07	13:51	30.1	40.8132	124.5613	312	559	7.19	12.57	286.7	692	29.0
17	40	15/07	13:54	35.8	40.9895	125.1113	420	>1,500	5.59	15.32	62.4	114	30.6
18	42	16/07	09:17	23.1	41.3230	124.5530	334	257	6.94	11.59	113.7	275	6.2
19	44	17/07	08:29	13.4	41.6540	124.4612	144	189	7.82	10.97	88.8	694	1.1
20	45	17/07	18:48	0.5	41.8235	124.4860	143	173	6.95	9.81	584.9	4,032	1.5
21	46	18/07	09:57	33.4	41.9802	124.8407	285	906	6.58	11.39	98.4	206	17.0
22	46	18/07	14:47	20.9	41.9838	125.0240	386	1,079	6.35	14.70	99.8	191	49.8
23	48	19/07	09:59	13.5	42.3223	124.6610	239	245	7.29	9.87	245.0	535	3.6
24	50	25/07	08:33	6.4	42.6518	124.7118	218	241	7.69	10.70	126.1	278	9.7
25	52	26/07	07:50	40.7	42.9898	125.1188	265	1,894	6.99	11.08	112.3	231	6.4
26	53	26/07	15:36	34.4	43.1528	124.7002	159	186	7.59	11.11	2,123.2	4,697	22.3
27	55	27/07	11:33	30.0	43.4932	124.9855	381	1,121	5.93	14.04	33.5	61	102.4
28	54	27/07	16:06	29.9	43.4907	124.6628	350	372	6.88	14.69	139.5	267	36.1
29	56	28/07	09:16	26.0	43.6627	124.6887	315	445	6.60	13.29	321.5	658	21.4

[a] Duration is the time during trawling between target depth and haul back.

[b] Gear depths were measured at the foot rope.

[c] Gear temperatures were measured at the head rope.

Table 5 (continued). Station and catch data summary of midwater trawls conducted by the *Shimada*.

Trawl	Transect	Date (DD/MM)	Time (PDT)	Duration (min.)[a]	Start position		Depth (m)		Temperature (°C)		Catch		
											Pacific hake		Other
					Lat. (°N)	Long. (°W)	Gear[b]	Bottom	Gear[c]	Surface	(kg)	Number	(kg)
30	58	29/07	08:34	20.5	43.9897	124.9608	368	445	6.85	14.53	150.7	351	47.3
31	59	29/07	13:18	8.1	44.1580	124.9715	267	283	7.01	12.96	198.6	489	3.7
32	60	30/07	08:11	4.0	44.3263	124.8523	149	369	7.40	10.84	270.8	742	14.0
33	64	01/08	10:54	17.9	44.9798	124.4445	293	307	6.73	12.92	272.9	755	6.7
34	65	01/08	16:54	8.0	45.1502	124.1990	134	142	7.38	11.68	792.3	2,285	11.7
35	67	02/08	14:18	trawl aborted because of gear issues							—	—	—
36	67	02/08	15:53	4.9	45.4898	124.5042	144	422	8.43	16.01	—	—	16.1
37	67	02/08	18:29	0.6	45.4868	124.2557	153	158	7.27	15.42	460.0	3,160	27.4
38	69	03/08	15:35	21.2	45.8172	124.7428	386	413	6.41	17.07	68.5	145	5.0
39	70	04/08	08:11	9.3	45.9942	124.5142	145	154	7.19	15.46	21.7	55	4,023.1
40	71	04/08	15:28	20.0	46.1572	124.4037	118	127	7.19	14.62	0.3	1	111.7
41	72	05/08	09:57	0.3	46.3253	124.6488	180	549	6.99	15.26	56.6	132	9.3
42	76	15/08	14:13	3.8	46.9848	124.8175	142	157	7.10	14.14	194.4	405	148.6
43	79	16/08	10:26	2.1	47.4858	124.7737	107	114	7.21	13.58	663.5	2,234	114.9
44	82	17/08	08:53	4.3	47.9910	125.1212	129	143	7.11	13.32	15.5	18	116.8
45	82	17/08	12:05	trawl aborted because of gear issues							—	—	—
46	82	17/08	13:20	5.1	47.9917	125.3378	264	555	6.80	14.24	9.8	18	19.6
47	84	18/08	14:10	19.8	48.3233	125.9002	379	542	6.15	14.90	73.8	821	31.1
48	100	24/08	09:13	4.7	50.9883	129.6678	251	487	6.38	14.09	38.9	56	7.6
49	100	24/08	12:23	7.8	50.9913	129.3268	153	178	6.89	13.56	—	—	165.8
50	143	31/08	11:37	25.0	52.1612	131.4145	393	504	5.81	14.66	12.2	13	49.0
51	137	01/09	19:30	trawl aborted because of gear issues							—	—	—
52	136	02/09	10:11	25.0	53.3290	132.9565	307	622	5.73	14.80	—	—	19.3
53	132	03/09	12:31	trawl aborted because of gear issues							—	—	5.5
54	132	03/09	16:15	20.1	53.9955	133.6072	430	444	5.12	14.72	—	—	7.0
55	131	04/09	12:41	trawl aborted because of gear issues							—	—	18.6
56	130	05/09	11:16	25.0	54.3243	133.9198	441	741	4.85	14.73	—	—	24.9
57	130	05/09	19:49	20.1	54.4005	133.1570	188	440	6.35	14.93	—	—	59.5

[a] Duration is the time during trawling between target depth and haul back.
[b] Gear depths were measured at the foot rope.
[c] Gear temperatures were measured at the head rope.

Table 6. Station and catch data summary of midwater trawls conducted by the Canadian FV *Nordic Pearl* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

Trawl	Transect	Date (DD/MM)	Time (PDT)	Duration (min.)[a]	Start position		Depth (m)		Catch	
					Latitude (°N)	Longitude (°W)	Target	Bottom	Pacific hake (kg)	Other (kg)
1	83	17/08	15:46	22.0	48.1571	125.9501	160	1,019	18.3	37.1
2	83	18/08	07:24	8.8	48.1600	125.0617	125	227	1,894.0	16.0
3	85	18/08	12:02	10.0	48.4987	125.0838	100	250	1,813.0	389.1
4	85	18/08	18:12	9.2	48.4747	126.1717	285	334	48.0	7.7
5	92	21/08	09:10	22.3	49.6581	127.4225	400	500	6.7	24.4
6	92	21/08	11:07	29.2	49.6540	127.4634	285	600	15.0	>4.5
7	94	21/08	17:32	14.8	49.9969	127.7666	165	400	574.6	13.1
8	96	22/08	12:06	12.7	50.3236	128.4185	280	600	274.0	21.6
9	98	23/08	07:56	2.3	50.6582	128.6464	125	171	938.0	>82.8
10	98	23/08	12:10	38.3	50.6579	129.3730	300	1,700	104.0	>0.0
11	101	24/08	07:14	8.4	51.1750	127.8627	95	112	—	57.3
12	104	26/08	07:47	15.7	51.6728	128.3501	120	140	343.0	227.8
13	104	26/08	15:19	12.6	51.6811	129.7368	220	250	148.0	1.6
14	107	31/08	16:46	12.3	52.1526	128.8696	150	195	8.0	>324.5
15	111	03/09	09:36	14.2	52.8191	130.3612	170	190	11,711.0	>0.0
16	120	05/09	14:37	27.9	54.5143	131.1906	110	160	—	>527.3
17	124	06/09	14:41	16.3	54.3631	132.2771	225	255	—	50.8

[a] Duration is the time during trawling between target depth and haul back.

Table 7. Station data summary of Methot trawls conducted by the NOAA Ship *Bell M. Shimada* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

Trawl	Transect	Date (DD/MM)	Time (PDT)	Duration (min.)[a]	Start position		Depth (m)		Temperature (°C)	
					Latitude (°N)	Longitude (°W)	Gear	Bottom	Gear	Surface
1	61	30/07	15:01	5.1	44.4880	124.7878	66	329	8.23	11.38
2	74	06/08	10:12	13.4	46.6514	124.8666	253	554	6.76	17.41
3	91	21/08	12:17	20.8	49.4899	127.2391	192	408	7.02	14.97
4	135	02/09	14:44	25.9	53.4777	133.3430	71	1,711	8.12	14.99
5	132	03/09	18:58	13.6	53.9960	133.5472	213	292	6.18	14.68
6	131	04/09	09:04	32.0	54.1599	133.7978	141	509	6.77	14.58
7	127	06/09	15:37	14.9	54.8215	134.2464	123	408	6.59	14.60
8	109/110	08/09	11:19	15.0	52.5618	130.1588	209	275	5.64	15.35
9	105	08/09	18:59	19.9	51.8341	130.2004	172	206	6.32	15.65
10	106/107	09/09	10:27	11.0	52.0685	130.6067	204	230	5.91	14.27
11	104	09/09	18:04	20.9	51.6652	130.3557	165	266	6.27	14.49
12	88	10/09	18:12	trawl aborted because of gear issues						
13	88	10/09	19:03	14.4	48.9906	126.6870	191	273	6.95	15.10
14	86/87	11/09	08:17	18.2	48.7163	126.2696	185	524	7.14	16.89

[a] Duration is the time during trawling between target depth and haul back.

Table 8. Species composition of catch, by weight, from 44 midwater trawls conducted in U.S. waters by the NOAA Ship *Bell M. Shimada* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

Common name	Scientific name	Weight (kg)	(%)	Numbers
Pacific hake	*Merluccius productus*	13,956.5	72.9	48,586
widow rockfish	*Sebastes entomelas*	3,821.7	20.0	3,958
yellowtail rockfish	*Sebastes flavidus*	490.6	2.6	538
sea pickle	*Pyrosoma* spp.	285.2	1.5	10,808
king-of-the-salmon	*Trachipterus altivelis*	110.6	0.6	35
jack mackerel	*Trachurus symmetricus*	105.2	0.5	101
Pacific herring	*Clupea pallasi*	68.1	0.4	856
sea tongue	*Pyrosoma atlanticum*	44.2	0.2	2,030
American shad	*Alosa sapidissima*	37.5	0.2	115
jellyfish	Scyphozoa	33.2	0.2	—
bocaccio	*Sebastes paucispinis*	26.5	0.1	22
sablefish	*Anoplopoma fimbria*	25.4	0.1	67
lanternfish	Myctophidae	16.6	<0.1	3,154
chilipepper	*Sebastes goodei*	16.6	<0.1	21
shortbelly rockfish	*Sebastes jordani*	13.4	<0.1	100
brown cat shark	*Apristurus brunneus*	13.4	<0.1	23
rougheye rockfish	*Sebastes aleutianus*	9.4	<0.1	5
boreal clubhook squid	*Onychoteuthis borealijaponicus*	8.4	<0.1	89
salp	Thaliacea	8.2	<0.1	—
black-spotted rockfish	*Sebastes melanostictus*	8.2	<0.1	3
robust clubhook squid	*Moroteuthis robusta*	7.5	<0.1	1
lingcod	*Ophiodon elongatus*	4.6	<0.1	2
rabbit-eared salp	*Thetys vagina*	4.5	<0.1	38
king salmon	*Oncorhynchus tshawytscha*	4.5	<0.1	3
Pacific sardine	*Sardinops sagax*	4.5	<0.1	20
canary rockfish	*Sebastes pinniger*	3.0	<0.1	4
sea nettle	*Chrysaora fuscescens*	2.9	<0.1	21
lion's mane jellyfish	*Cyanea capillata*	2.5	<0.1	3
Pacific ocean perch	*Sebastes alutus*	2.5	<0.1	3
egg-yolk jellyfish	*Phacellophora camtschatica*	2.4	<0.1	6
Pacific lamprey	*Lampetra tridentata*	2.2	<0.1	1
squid	Teuthida	1.8	<0.1	136
darkblotched rockfish	*Sebastes crameri*	1.5	<0.1	3
California market squid	*Loligo opalescens*	1.0	<0.1	23
chub mackerel	*Scomber japonicus*	1.0	<0.1	2
Pacific pomfret	*Brama japonica*	0.8	<0.1	1
spiny dogfish	*Squalus acanthias*	0.5	<0.1	5
hatchetfish	Sternoptychidae	0.4	<0.1	19
splitnose rockfish	*Sebastes diploproa*	0.4	<0.1	1
California headlightfish	*Diaphus theta*	0.3	<0.1	69
pelagic red crab	*Pleuroncodes planipes*	0.3	<0.1	27
olive rockfish	*Sebastes serranoides*	0.3	<0.1	1
glass shrimp	*Pasiphaea pacifica*	0.2	<0.1	211
northern anchovy	*Engraulis mordax*	0.1	<0.1	4

Table 8 (continued). Species composition of catch, by weight, from 44 midwater trawls conducted in U.S. waters by the *Shimada*.

Common name	Scientific name	Weight (kg)	(%)	Numbers
shining tubeshoulder	*Sagamichthys abei*	<0.1	<0.1	1
crystal jellyfish	*Aequorea victoria*	<0.1	<0.1	1
deepwater eelpout	*Lycodapus endemoscotus*	<0.1	<0.1	2
northern spearnose poacher	*Agonopsis vulsa*	<0.1	<0.1	1
California lanternfish	*Symbolophorus californiensis*	<0.1	<0.1	5
viperfish	Chauliodontidae	<0.1	<0.1	6
scaleless dragonfish	Melanostomiidae	<0.1	<0.1	2
shrimp	Decapoda	<0.1	<0.1	19
Pacific hatchetfish	*Argyropelecus affinis*	<0.1	<0.1	1
fish	Osteichthyes	<0.1	<0.1	1
medusafish	*Icichthys lockingtoni*	<0.1	<0.1	1
Pacific viperfish	*Chauliodus macouni*	<0.1	<0.1	1
slender barracudina	*Lestidiops ringens*	<0.1	<0.1	1
scabbardfish	*Lepidopus xantusi*	<0.1	<0.1	1

Table 9. Species composition of catch, by weight, from seven midwater trawls conducted in Canadian waters by the NOAA Ship *Bell M. Shimada* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

Common name	Scientific name	Weight (kg)	(%)	Numbers
Pacific herring	*Clupea pallasi*	163.7	40.1	1,450
Pacific hake	*Merluccius productus*	51.0	12.5	69
walleye pollock	*Theragra chalcogramma*	50.8	12.4	33
moon jellyfish	*Aurelia* spp.	32.6	8.0	—
rougheye rockfish	*Sebastes aleutianus*	31.6	7.7	23
redstripe rockfish	*Sebastes proriger*	16.4	4.0	25
chum salmon	*Oncorhynchus keta*	15.9	3.9	3
canary rockfish	*Sebastes pinniger*	10.8	2.6	5
silvergray rockfish	*Sebastes brevispinis*	7.8	1.9	4
black-spotted rockfish	*Sebastes melanostictus*	6.2	1.5	3
Pacific ocean perch	*Sebastes alutus*	4.8	1.2	9
egg-yolk jellyfish	*Phacellophora camtschatica*	4.0	1.0	4
widow rockfish	*Sebastes entomelas*	3.5	0.8	6
yellowtail rockfish	*Sebastes flavidus*	3.2	0.8	2
northern lampfish	*Stenobrachius leucopsarus*	2.0	0.5	227
magistrate armhook squid	*Berryteuthis magister*	1.1	0.3	5
sablefish	*Anoplopoma fimbria*	0.5	0.1	2
armhook squid	*Gonatus* spp.	0.4	<0.1	91
California headlightfish	*Diaphus theta*	0.4	<0.1	65
comb jelly	Ctenophora	0.3	<0.1	21
sunrise jellyfish	*Chrysaora melanaster*	0.3	<0.1	3
arrowtooth flounder	*Atheresthes stomias*	0.3	<0.1	1
jellyfish	Scyphozoa	0.2	<0.1	—
sea tongue	*Pyrosoma atlanticum*	0.2	<0.1	29
glass shrimp	*Pasiphaea pacifica*	0.1	<0.1	147
minimal armhook squid	*Berryteuthis anonychus*	0.1	<0.1	1
salp	Thaliacea	<0.1	<0.1	—
lanternfish	Myctophidae	<0.1	<0.1	1
long armed jewel squid	*Histioteuthis hoylei*	<0.1	<0.1	—
northern pearleye	*Benthalbella dentata*	<0.1	<0.1	3
euphausiid	Euphausiacea	<0.1	<0.1	—
rockfish	*Sebastes* spp.	<0.1	<0.1	13
slender barracudina	*Lestidiops ringens*	<0.1	<0.1	3
Pacific viperfish	*Chauliodus macouni*	<0.1	<0.1	11
viperfish	Chauliodontidae	<0.1	<0.1	2
pencil smelt	Microstomatidae	<0.1	<0.1	1
shortbelly rockfish	*Sebastes jordani*	<0.1	<0.1	1
flatfish	Pleuronectiformes	<0.1	<0.1	3
lanternfish	*Tarletonbeania* spp.	<0.1	<0.1	1
fish	Osteichthyes	<0.1	<0.1	3

Table 10. Species composition of catch, by weight, from two midwater trawls conducted in U.S. waters by the Canadian FV *Nordic Pearl* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

Common name	Scientific name	Weight (kg)
Pacific hake	*Merluccius productus*	1,912.3
sea pickle	*Pyrosoma* spp.	34.8
king salmon	*Oncorhynchus tshawytscha*	5.8
spiny dogfish	*Squalus acanthias*	1.9
yellowtail rockfish	*Sebastes flavidus*	1.3
sablefish	*Anoplopoma fimbria*	0.6
walleye pollock	*Theragra chalcogramma*	0.4
bocaccio	*Sebastes paucispinis*	0.2
Pacific herring	*Clupea pallasi*	n/a

Table 11. Species composition of catch, by weight, from 15 midwater trawls conducted in Canadian waters by the Canadian FV *Nordic Pearl* during the 2017 joint U.S. and Canada Pacific herring integrated acoustic and trawl survey.

Common name	Scientific name	Weight (kg)
Pacific hake	*Merluccius productus*	15,983.3
walleye pollock	*Theragra chalcogramma*	>1,410.8
rockfish	*Sebastes* spp.	>140.1
Pacific herring	*Clupea pallasi*	>76.1
arrowtooth flounder	*Atheresthes stomias*	>24.4
yellowtail rockfish	*Sebastes flavidus*	>24.3
rougheye rockfish	*Sebastes aleutianus*	11.5
sea pickle	*Pyrosoma* spp.	10.9
Pacific ocean perch	*Sebastes alutus*	9.8
king salmon	*Oncorhynchus tshawytscha*	8.6
silvergray rockfish	*Sebastes brevispinis*	>6.7
sablefish	*Anoplopoma fimbria*	3.4
jack mackerel	*Trachurus symmetricus*	1.5
lanternfish	Myctophidae	1.3
widow rockfish	*Sebastes entomelas*	1.2
brown cat shark	*Apristurus brunneus*	0.7
English sole	*Parophrys vetulus*	0.5
spiny dogfish	*Squalus acanthias*	>0.5
redstripe rockfish	*Sebastes proriger*	>0.3
California headlightfish	*Diaphus theta*	n/a
eulachon	*Thaleichthys pacificus*	n/a

Table 12. Numbers of Pacific hake biological samples and measurements collected on the NOAA Ship *Bell M. Shimada* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

Trawl	Length	Otoliths	Fish weight	Maturity	Stomach	Ovary/Liver	Fin Clip
1	331	52	52	52	5	0	43
2	379	51	51	51	5	7	48
3	429	51	51	51	5	4	48
4	415	53	53	53	5	2	48
5	286	52	52	52	5	6	49
6	2	2	2	2	2	1	0
7	21	21	21	21	4	2	21
8	430	51	51	51	4	4	47
9	23	23	23	23	5	0	23
10	395	49	49	49	5	0	48
11				trawl aborted			
12	50	50	50	50	5	3	48
13	397	57	57	57	5	1	48
14	403	50	50	50	5	0	48
15	457	55	55	55	5	0	48
16	419	50	50	50	5	0	48
17	114	51	51	51	5	3	47
18	267	46	49	49	5	0	46
19	250	50	50	50	5	2	48
20	242	50	50	50	5	0	48
21	206	49	49	49	5	1	48
22	191	50	50	50	5	0	48
23	416	51	51	51	5	0	48
24	269	56	56	56	4	3	47
25	226	58	58	58	4	2	48
26	397	54	54	54	5	4	48
27	61	61	61	61	5	3	48
28	271	43	45	45	5	0	45
29	396	50	50	50	5	2	48
30	321	57	57	57	3	0	48
31	396	59	59	59	5	0	48
32	462	62	62	62	5	0	48
33	444	64	64	64	5	0	48
34	419	56	56	56	5	3	48
35				trawl aborted			
36	0	0	0	0	0	0	0
37	421	47	47	47	4	2	47
38	145	51	51	51	5	0	48
39	55	55	55	55	5	4	48
40	1	1	1	1	1	0	1
41	132	50	50	50	5	0	48
42	65	65	65	65	0	1	0
43	572	89	89	89	0	1	0
44	18	18	18	18	0	0	0

Table 12 (continued). Numbers of Pacific hake biological samples and measurements collected on the *Shimada*.

Trawl	Length	Otoliths	Fish weight	Maturity	Stomach	Ovary/Liver	Fin Clip
45				trawl aborted			
46	18	18	18	18	0	1	0
47	123	50	50	50	0	0	0
48	56	56	56	56	4	0	0
49	0	0	0	0	0	0	0
50	13	13	13	13	4	3	13
51				trawl aborted			
52	0	0	0	0	0	0	0
53				trawl aborted			
54	0	0	0	0	0	0	0
55				trawl aborted			
56	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0
Totals	11,404	2,147	2,152	2,152	184	65	1,677

Table 13. Numbers of Pacific hake biological samples and measurements collected on the Canadian FV *Nordic Pearl* during the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey.

Trawl	Length	Otoliths	Fish weight	Maturity
1	355	52	52	0
2	350	50	50	50
3	347	50	50	50
4	356	51	51	10
5	13	13	13	13
6	23	23	23	23
7	353	50	50	50
8	370	50	50	50
9	369	55	55	54
10	151	50	50	50
11	0	0	0	0
12	353	50	50	50
13	174	50	50	50
14	6	6	6	6
15	356	52	52	52
16	0	0	0	0
17	0	0	0	0
Totals	3,576	602	602	508

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